US006466984B1

(12) **United States Patent**
Naveh et al.

(10) **Patent No.: US 6,466,984 B1**
(45) **Date of Patent: Oct. 15, 2002**

(54) **METHOD AND APPARATUS FOR POLICY-BASED MANAGEMENT OF QUALITY OF SERVICE TREATMENTS OF NETWORK DATA TRAFFIC FLOWS BY INTEGRATING POLICIES WITH APPLICATION PROGRAMS**

(75) Inventors: **Arad Naveh**; **Itzhak Parnafes**, both of Cupertino; **Shai Mohaban**, Sunnyvale; **Steven M. Woo**, Redwood Shores, all of CA (US)

(73) Assignee: **Cisco Technology, Inc.**, San Jose, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/346,967**

(22) Filed: **Jul. 2, 1999**

(51) **Int. Cl.**[7] **G06F 15/16**

(52) **U.S. Cl.** **709/228**; 709/220; 709/221; 709/222; 709/226; 709/227; 370/229; 370/230; 370/231; 370/235; 370/236

(58) **Field of Search** 709/220, 221, 709/222, 226, 227, 228; 370/229, 230, 231, 235, 236

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,970,064 A		10/1999	Clark et al.	370/351
6,021,439 A	*	2/2000	Turek et al.	709/224
6,028,842 A	*	2/2000	Chapman et al.	370/235
6,104,700 A		8/2000	Haddock et al.	370/235
6,118,760 A	*	9/2000	Zaumen et al.	370/229
6,154,776 A	*	11/2000	Martin	709/226
6,169,748 B1		1/2001	Barbas et al.	370/468
6,301,253 B1	*	10/2001	Ichikawa	370/395
6,301,613 B1		10/2001	Ahlstrom et al.	709/223
6,327,618 B1		12/2001	Ahlstrom et al.	709/223
6,363,429 B1	*	3/2002	Ketcham	709/235

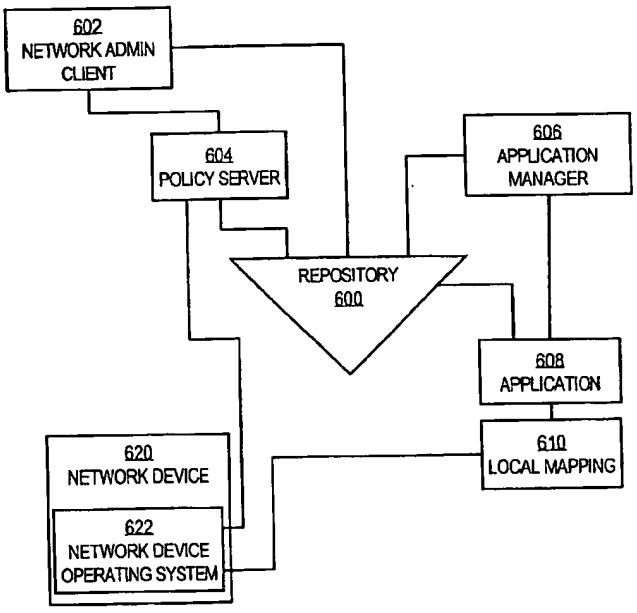
* cited by examiner

Primary Examiner—Saleh Najjar
(74) *Attorney, Agent, or Firm*—Hickman Palermo Truong & Becker LLP

(57) **ABSTRACT**

A method and apparatus for policy-based management of quality of service treatments of network data traffic flows by integrating policies with application programs are described. In one embodiment, a quality of service value is selectively associated with a flow of information generated by an application program and directed to a network device. Mappings representing an abstract policy and associating a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program are created and stored in a repository that is accessible by the application program. The mappings are converted into one or more settings of the network device. The policy is enforced at the network device in response to receiving traffic from the application program that matches the traffic flow type. The settings may be Differentiated Services Code Points or may be RSVP+ messages. Policies may be represented by statements stored in a directory schema. Each policy statement is represented by nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising one of the quality of service treatments. The nodes start at a root node having a distinguished name in the directory.

64 Claims, 10 Drawing Sheets



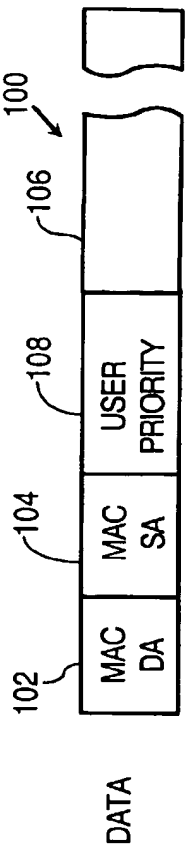


FIG. 1A (Prior Art)

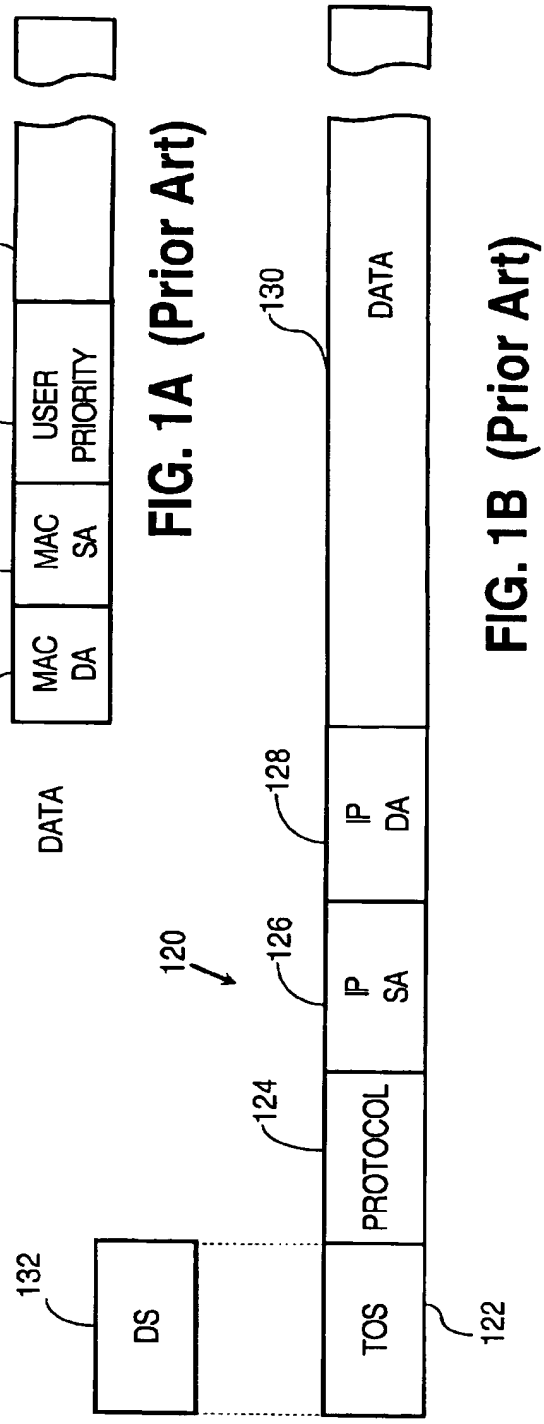


FIG. 1B (Prior Art)

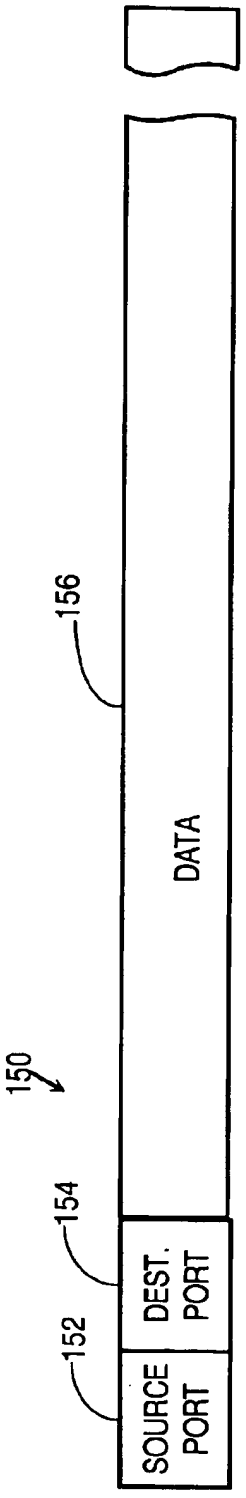


FIG. 1C (Prior Art)

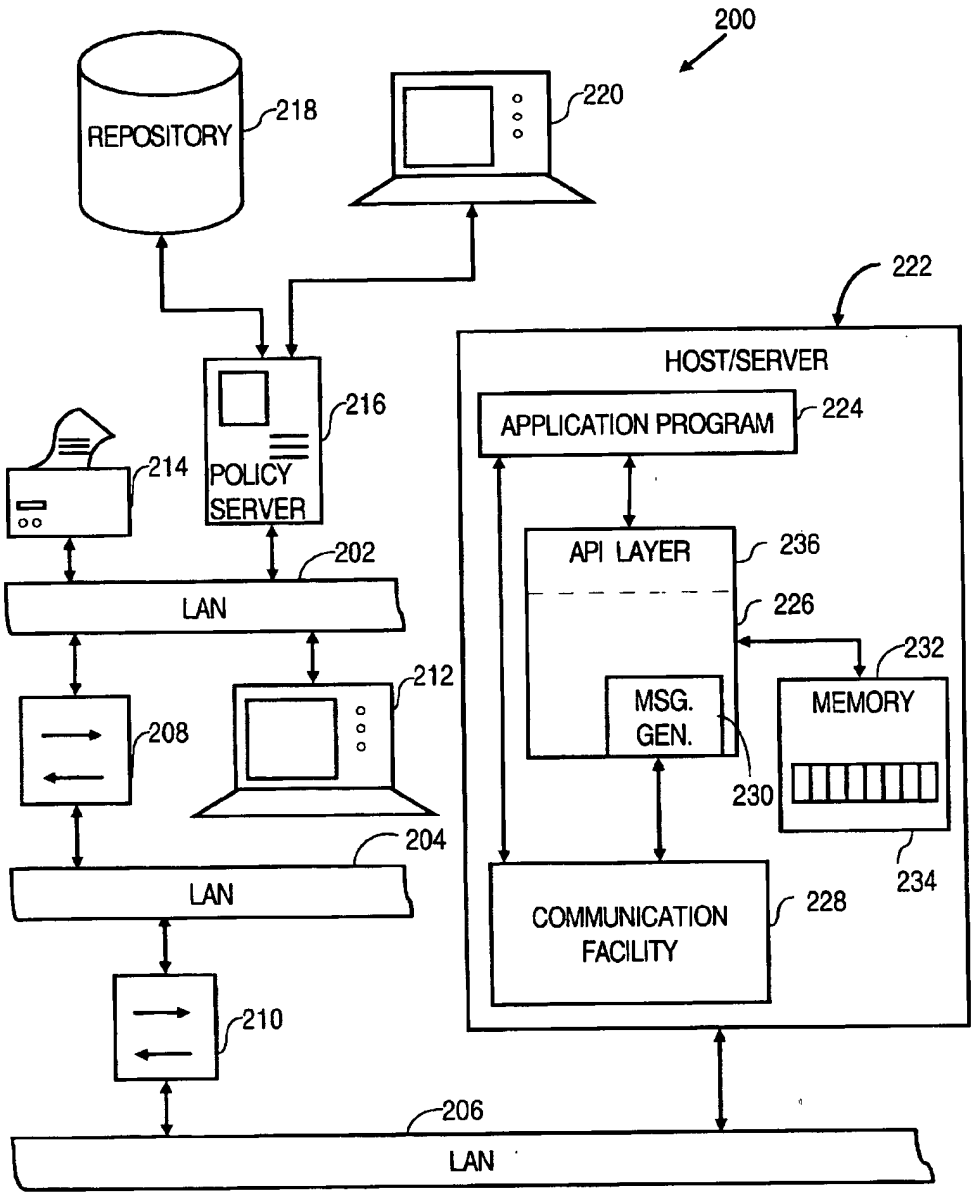

200
REPOSITORY
218
220
222
HOST/SERVER
APPLICATION PROGRAM
224
216
POLICY SERVER
214
API LAYER
236
226
232
MSG. GEN.
MEMORY
230
202
LAN
212
208
204
LAN
234
COMMUNICATION FACILITY
228
210
206
LAN

FIG. 2

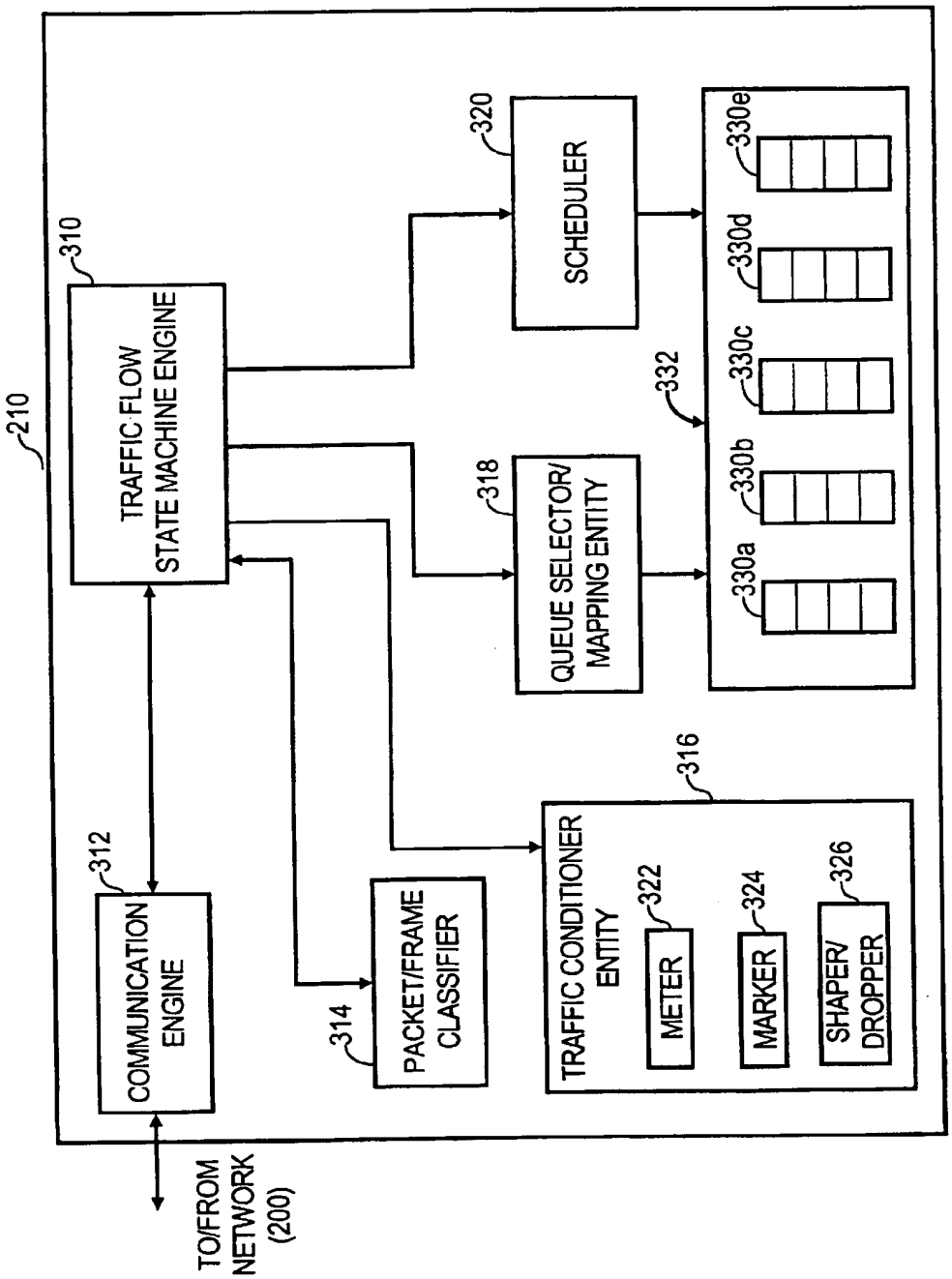

210
TRAFFIC FLOW STATE MACHINE ENGINE
310
SCHEDULER
320
QUEUE SELECTOR/ MAPPING ENTITY
318
332
330a
330b
330c
330d
330e
COMMUNICATION ENGINE
312
PACKET/FRAME CLASSIFIER
314
TRAFFIC CONDITIONER ENTITY
316
METER
322
MARKER
324
SHAPER/ DROPPER
326
TO/FROM NETWORK (200)

FIG. 3

FIG. 4

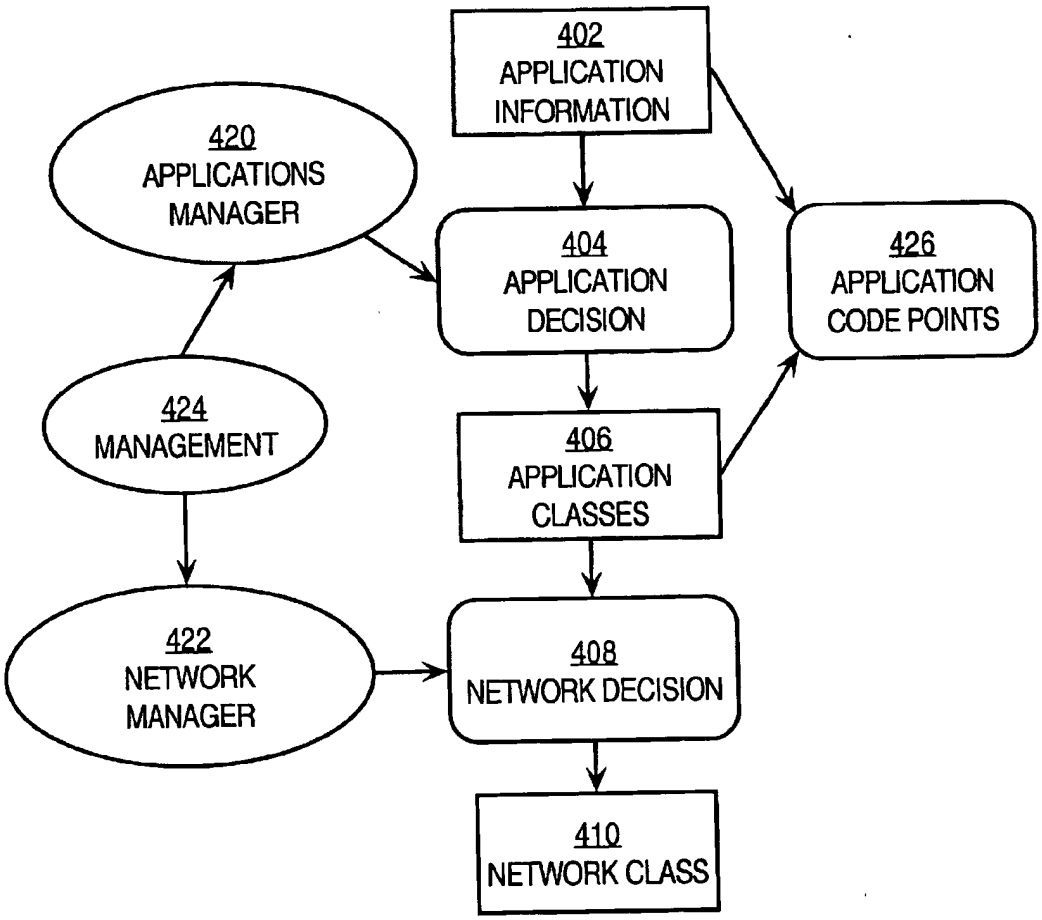

402
APPLICATION
INFORMATION
420
APPLICATIONS
MANAGER
404
APPLICATION
DECISION
426
APPLICATION
CODE POINTS
424
MANAGEMENT
406
APPLICATION
CLASSES
422
NETWORK
MANAGER
408
NETWORK DECISION
410
NETWORK CLASS

FIG. 5

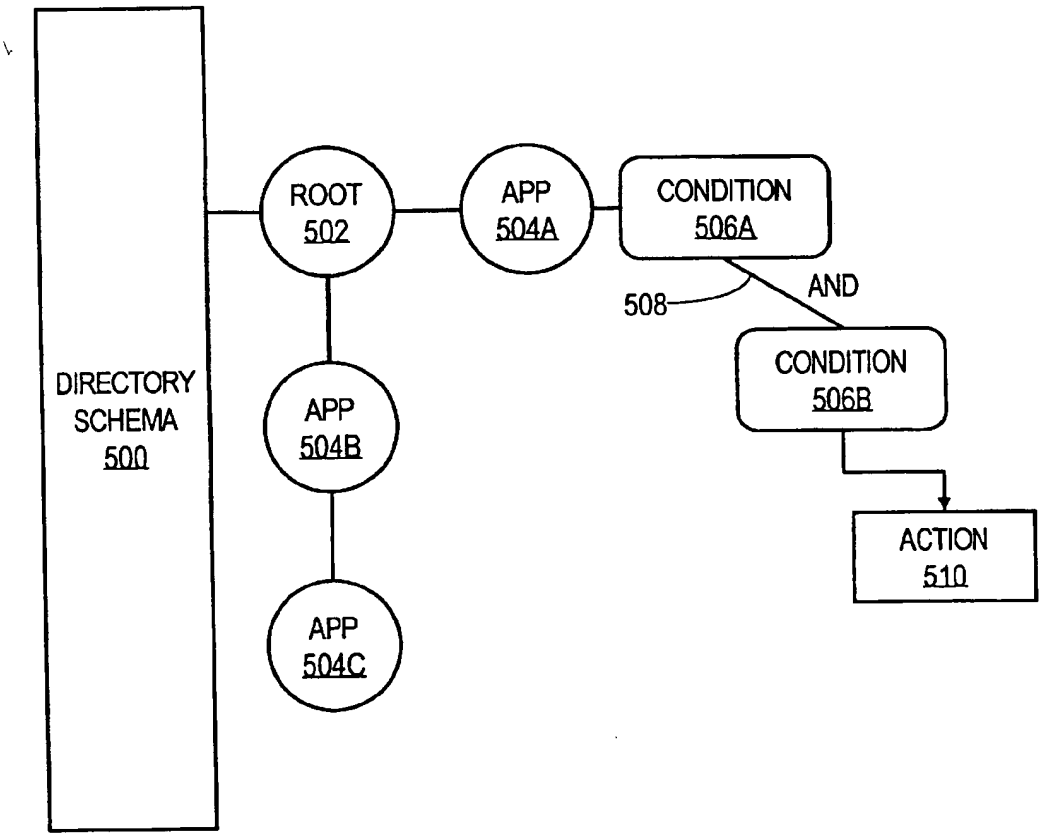

DIRECTORY SCHEMA 500
ROOT 502
APP 504A
CONDITION 506A
508
AND
CONDITION 506B
ACTION 510
APP 504B
APP 504C

FIG. 6A

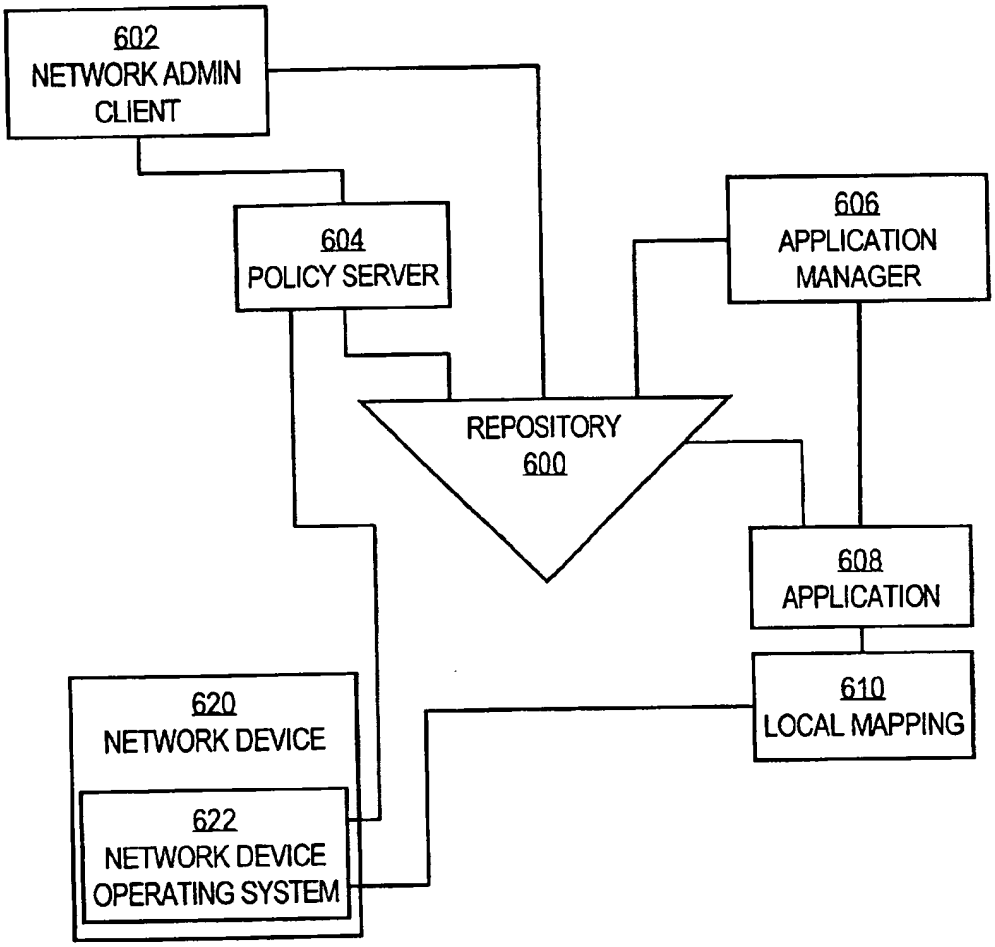

602
NETWORK ADMIN
CLIENT
604
POLICY SERVER
606
APPLICATION
MANAGER
REPOSITORY
600
608
APPLICATION
610
LOCAL MAPPING
620
NETWORK DEVICE
622
NETWORK DEVICE
OPERATING SYSTEM

FIG. 6B

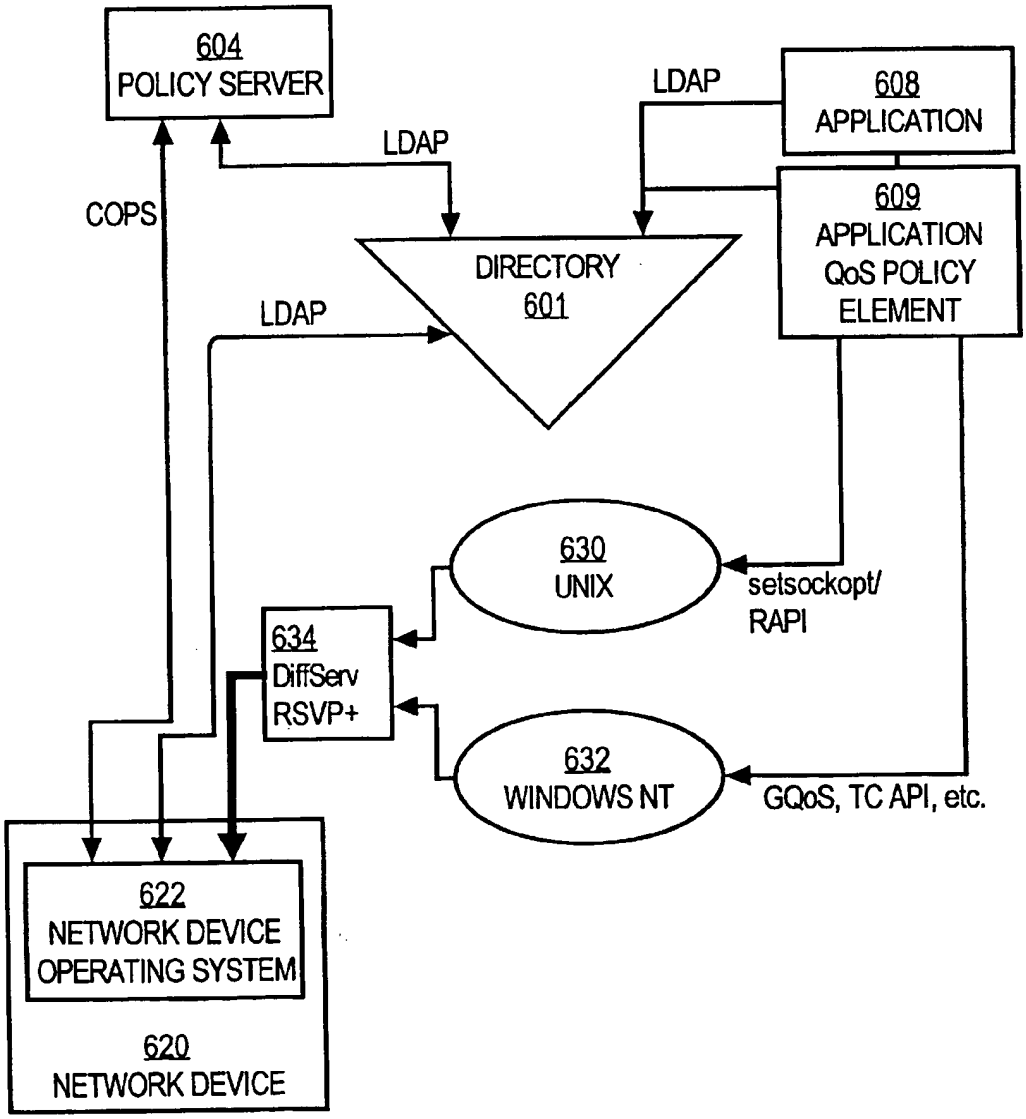

604
POLICY SERVER
LDAP
608
APPLICATION
LDAP
COPS
609
APPLICATION
QoS POLICY
ELEMENT
DIRECTORY
601
LDAP
630
UNIX
setsockopt/
RAPI
634
DiffServ
RSVP+
632
WINDOWS NT
GQoS, TC API, etc.
622
NETWORK DEVICE
OPERATING SYSTEM
620
NETWORK DEVICE

FIG. 7A

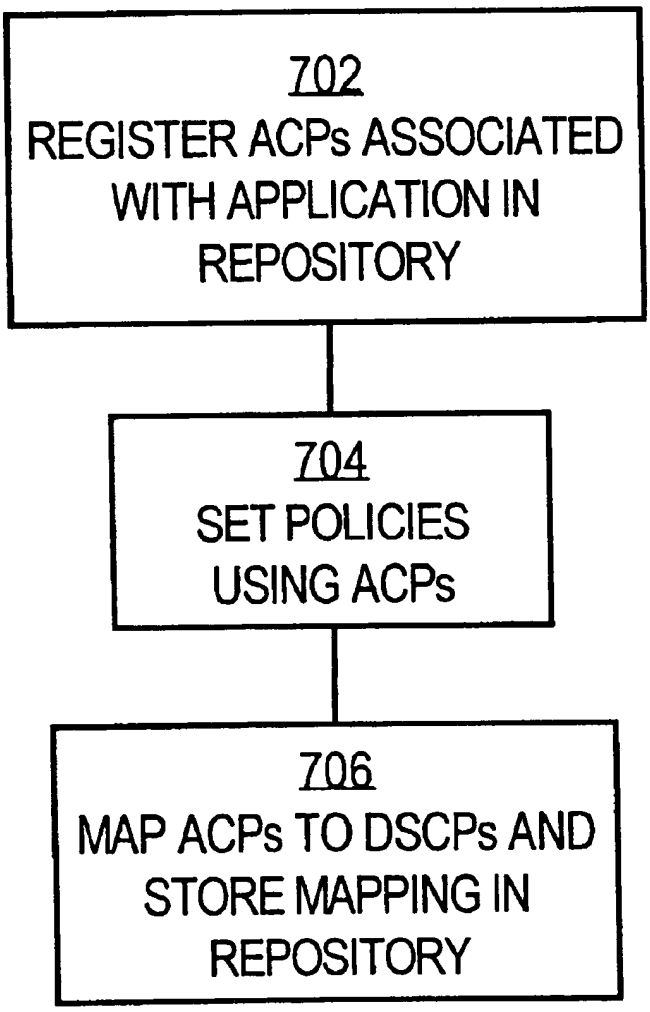
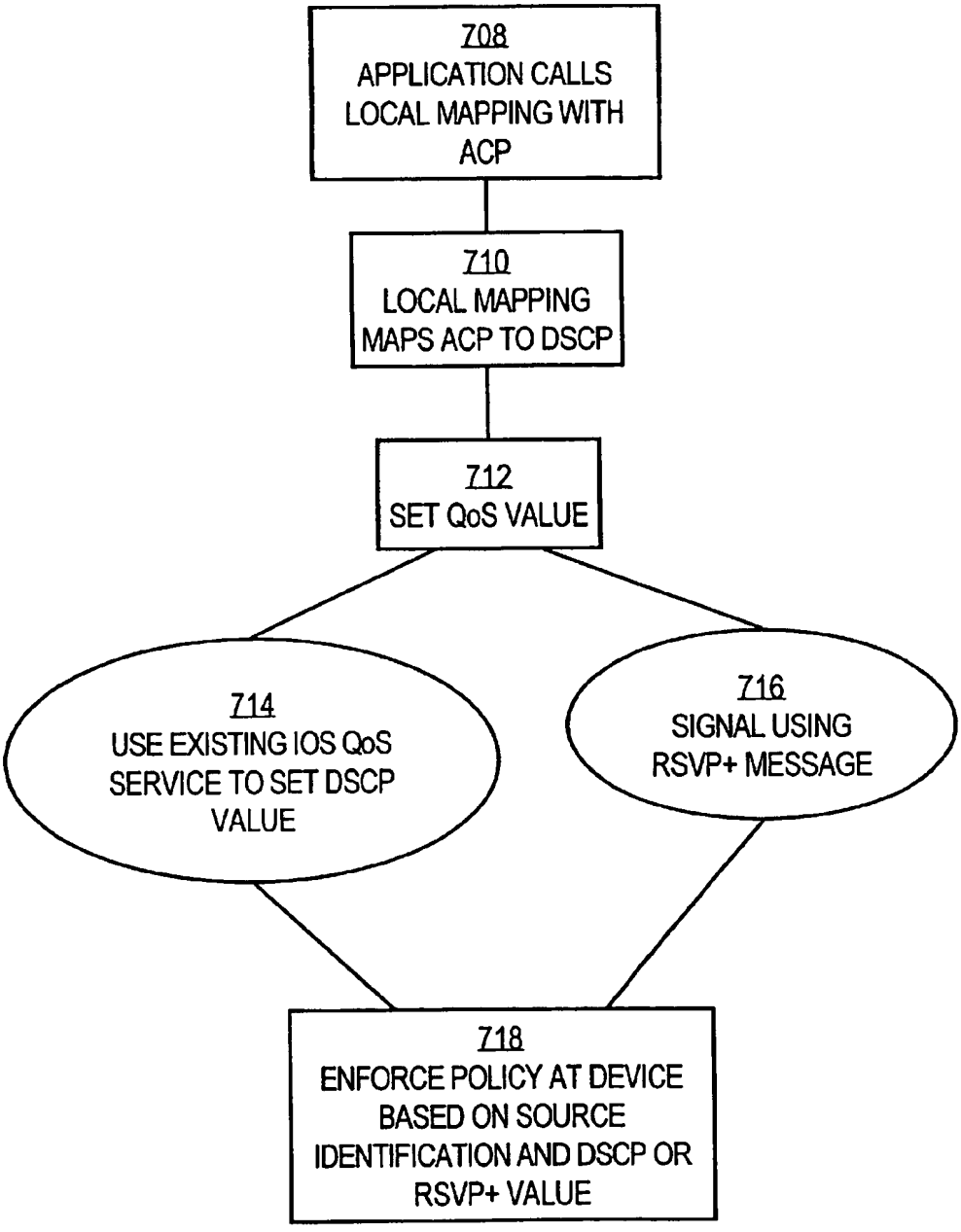

702
REGISTER ACPs ASSOCIATED WITH APPLICATION IN REPOSITORY
704
SET POLICIES USING ACPs
706
MAP ACPs TO DSCPs AND STORE MAPPING IN REPOSITORY

FIG. 7B


708
APPLICATION CALLS LOCAL MAPPING WITH ACP
710
LOCAL MAPPING MAPS ACP TO DSCP
712
SET QoS VALUE
714
USE EXISTING IOS QoS SERVICE TO SET DSCP VALUE
716
SIGNAL USING RSVP+ MESSAGE
718
ENFORCE POLICY AT DEVICE BASED ON SOURCE IDENTIFICATION AND DSCP OR RSVP+ VALUE

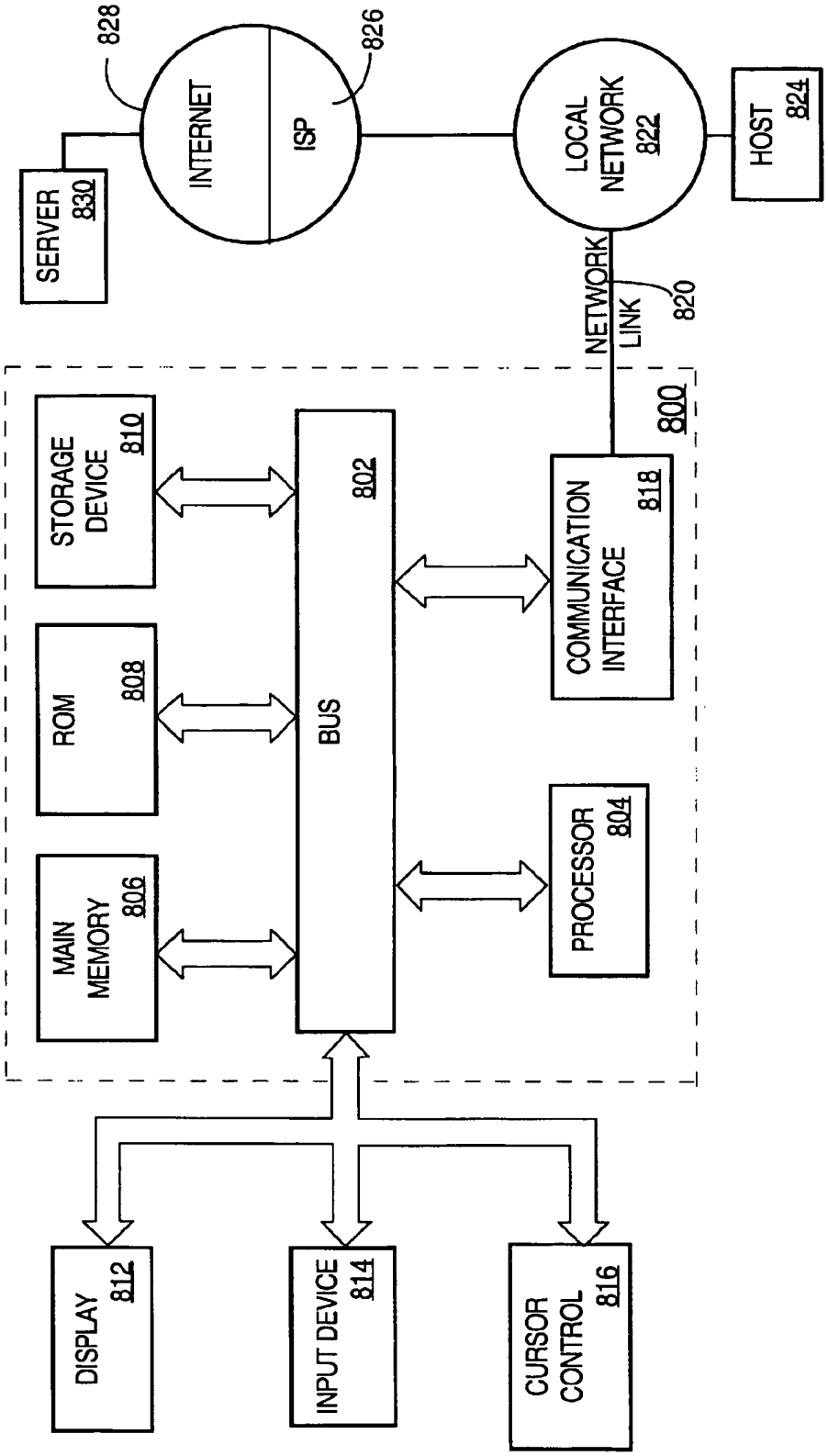

828
826
INTERNET
ISP
LOCAL NETWORK 822
HOST 824
SERVER 830
NETWORK LINK 820
800
STORAGE DEVICE 810
BUS 802
COMMUNICATION INTERFACE 818
ROM 808
MAIN MEMORY 806
PROCESSOR 804
DISPLAY 812
INPUT DEVICE 814
CURSOR CONTROL 816

FIG. 8

METHOD AND APPARATUS FOR POLICY-BASED MANAGEMENT OF QUALITY OF SERVICE TREATMENTS OF NETWORK DATA TRAFFIC FLOWS BY INTEGRATING POLICIES WITH APPLICATION PROGRAMS

RELATED APPLICATIONS

This application is related to prior, co-pending applications Ser. No. 09/179,036, filed Oct. 26, 1998, entitled "Method and apparatus for defining and implementing high-level quality of service policies in computer networks," now U.S. Pat. No. 6,167,445 and Ser. No. 09/206,067, filed Dec. 4, 1998, entitled "Method and apparatus for identifying network data traffic flows and for applying quality of service treatments to the flows." now U.S. Pat. No. 6,286,052.

FIELD OF THE INVENTION

The present invention relates generally to computer networks, and more specifically, to a method and apparatus for policy-based management of quality of service treatments of network data traffic flows by integrating policies with application programs.

BACKGROUND OF THE INVENTION

A computer network typically comprises a plurality of interconnected entities that transmit ("source") or receive ("sink") data frames. A common type of computer network is a local area network ("LAN") that generally comprises a privately owned network within a single building or campus. LANs employ a data communication protocol (LAN standard) such as Ethernet, FDDI, or Token Ring, that defines the functions performed by the data link and physical layers of a communications architecture (i.e., a protocol stack), such as the Open Systems Interconnection (OSI) Reference Model. In many instances, multiple LANs may be interconnected by point-to-point links, microwave transceivers, satellite hookups, etc., to form a wide area network ("WAN"), metropolitan area network ("MAN") or intranet. These internetworks may be coupled through one or more gateways to the global, packet-switched internetwork known as the Internet.

Each network entity preferably includes network communication software, which may operate in accordance with Transport Control Protocol/Internet Protocol (TCP/IP). TCP/IP generally consists of a set of rules defining how entities interact with each other. In particular, TCP/IP defines a series of communication layers, including a transport layer and a network layer. At the transport layer, TCP/IP includes both the User Data Protocol (UDP), which is a connectionless transport protocol, and TCP which is a reliable, connection-oriented transport protocol. When a process at one network entity wishes to communicate with another entity, it formulates one or more messages and passes them to the upper layer of the TCP/IP communication stack. These messages are passed down through each layer of the stack where they are encapsulated into packets and frames. Each layer also adds information in the form of a header to the messages. The frames are then transmitted over the network links as bits. At the destination entity, the bits are re-assembled and passed up the layers of the destination entity's communication stack. At each layer, the corresponding message headers are also stripped off, thereby recovering the original message which is handed to the receiving process.

One or more intermediate network devices are often used to couple LANs together and allow the corresponding entities to exchange information. For example, a bridge may be used to provide a "bridging" function between two or more LANs. Alternatively, a switch may be utilized to provide a "switching" function for transferring information, such as data frames or packets, among entities of a computer network. Typically, the switch is a computer having a plurality of ports that couple the switch to several LANs and to other switches. The switching function includes receiving data frames at a source port and transferring them to at least one destination port for receipt by another entity. Switches may operate at various levels of the communication stack. For example, a switch may operate at Layer 2 which, in the OSI Reference Model, is called the data link layer, and includes the Logical Link Control (LLC) and Media Access Control (MAC) sub-layers.

Other intermediate devices, commonly known as routers, may operate at higher communication layers, such as Layer 3, which in TCP/IP networks corresponds to the Internet Protocol (IP) layer. IP data packets include a corresponding header which contains an IP source address and an IP destination address. Routers or Layer 3 switches may re-assemble or convert received data frames from one LAN standard (e.g., Ethernet) to another (e.g., Token Ring). Thus, Layer 3 devices are often used to interconnect dissimilar subnetworks. Some Layer 3 intermediate network devices may also examine the transport layer headers of received messages to identify the corresponding TCP or UDP port numbers being utilized by the corresponding network entities. Many applications are assigned specific, fixed TCP and/or UDP port numbers in accordance with Request For Comments (RFC) 1700. For example, TCP/UDP port number 80 corresponds to the Hypertext Transport Protocol (HTTP), while port number 21 corresponds to File Transfer Protocol (FTP) service.

ALLOCATION OF NETWORK RESOURCES

Computer networks include numerous services and resources for use in moving traffic throughout the network. For example, different network links, such as Fast Ethernet, Asynchronous Transfer Mode (ATM) channels, network tunnels, satellite links, etc., offer unique speed and bandwidth capabilities. Particular intermediate devices also include specific resources or services, such as number of priority queues, filter settings, availability of different queue selection strategies, congestion control algorithms, etc.

Individual frames or packets can be marked so that intermediate devices may treat them in a predetermined manner. For example, the Institute of Electrical and Electronics Engineers (IEEE) describes additional information for the MAC header of Data Link Layer frames in Appendix 802.1p to the 802.1D bridge standard.

FIG. 1A is a partial block diagram of a Data Link frame 100 that includes a MAC destination address (DA) field 102, a MAC source address (SA) field 104 and a data field 106. According to the 802.1Q standard, a user_priority field 108, among others, is inserted after the MAC SA field 104. The user_priority field 108 may be loaded with a predetermined value (e.g., 0–7) that is associated with a particular treatment, such as background, best effort, excellent effort, etc. Network devices, upon examining the user_priority field 108 of received Data Link frames 100, apply the corresponding treatment to the frames. For example, an intermediate device may have a plurality of transmission priority queues per port, and may assign frames to different queues of a destination port on the basis of the frame's user priority value.

FIG. 1B is a partial block diagram of a Network Layer packet **120** corresponding to the Internet Protocol. Packet **120** includes a type_of_service (ToS) field **122**, a protocol field **124**, an IP source address (SA) field **126**, an IP destination address (DA) field **128** and a data field **130**. The ToS field **122** is used to specify a particular service to be applied to the packet **120**, such as high reliability, fast delivery, accurate delivery, etc., and comprises a number of sub-fields. The sub-fields may include a 3-bit IP precedence (IPP) field and three one-bit flags that signify Delay, Throughput, and Reliability. By setting the flags, a device may indicate whether delay, throughput, or reliability is most important for the traffic associated with the packet. Version 6 of the Internet Protocol (Ipv6) defines a traffic class field, which is also intended to be used for defining the type of service to be applied to the associated packet.

A working group of the Internet Engineering Task Force (IETF) has proposed replacing the ToS field **122** of Network Layer packets **120** with a one-octet differentiated services (DS) field **132** that can be loaded with a differentiated services codepoint. Layer **3** devices that are DS compliant apply a particular per-hop forwarding behavior to data packets based on the contents of their DS fields **132**. Examples of per-hop forwarding behaviors include expedited forwarding and assured forwarding. The DS field **132** is typically loaded by DS compliant intermediate devices located at the border of a DS domain, which is a set of DS compliant intermediate devices under common network administration. Thereafter, interior DS compliant devices along the path apply the corresponding forwarding behavior to the packet **120**.

FIG. 1C is a partial block diagram of a Transport Layer packet **150** that preferably includes a source port field **152**, a destination port field **154**, and a data field **156**, among others. Fields **152, 154** preferably are loaded with the TCP or UDP port numbers that are utilized by corresponding network entities.

SERVICE LEVEL AGREEMENTS

To interconnect dispersed computer networks, many organizations rely on the infrastructure and facilities of Internet Service Providers (ISPs). For example, an organization may lease one or more T1 lines to interconnect various LANs. Each organization enters into a service-level agreement with its ISP. The service level agreements include one or more traffic specifications. The traffic specifications may place limits on the amount of resources that the organization may consume for a given price.

For example, an organization may agree not to send traffic that exceeds a certain bandwidth, e.g., 1 Mb/s. Traffic entering the service provider's network is monitored to ensure that it complies with the relevant traffic specifications and is thus "in profile." Traffic that exceeds a traffic specification, and is therefore "out of profile," may be dropped or shaped or may cause an accounting change. Alternatively, the service provider may mark the traffic as exceeding the traffic specification, but allow it to proceed through the network anyway. If there is congestion, an intermediate network device may drop such marked traffic first in an effort to relieve the congestion.

MULTIPLE TRAFFIC FLOWS

A process executing at a network entity may generate hundreds or thousands of traffic flows that are transmitted across a network. Generally, a traffic flow is a set of messages (frames and/or packets) that typically correspond to a particular task, transaction or operation (e.g., a print transaction) and may be identified by various network and transport parameters, such as source and destination IP addresses, source and destination TCP/UDP port numbers, and transport protocol.

The treatment that is applied to different traffic flows may vary depending on the particular traffic flow at issue. For example, an online trading application may generate stock quote messages, stock transaction messages, transaction status messages, corporate financial information messages, print messages, data backup messages, etc. A network administrator may wish to apply a different policy or service treatment ("quality of service" or "QoS") to each traffic flow. In particular, the network administrator may want a stock quote message to be given higher priority than a print transaction. Similarly, a $1 million stock transaction message for a premium client should be assigned higher priority than a $100 stock transaction message for a standard customer.

DEFICIENCIES OF PAST APPROACHES

Currently, application programs that execute in network devices rarely invoke QoS functions, and therefore they do not take full advantage of QoS features that are available in the network devices.

Some intermediate network devices can distinguish among multiple traffic flows and can apply different QoS to the flows. Generally, QoS may be applied by such network devices based on the IP address or port number associated with a traffic flow. This approach has several advantages. It is centralized, it works with multiple applications, and it is application independent. However, there are also significant disadvantages. It is based on limited or no knowledge of application traffic flows. A network manager cannot define and apply QoS policies for individual applications. It has only limited applicability to encrypted packets.

In another known approach, applications use QoS signaling mechanisms, such as RSVP or differentiated services ("DS" or "DiffServ"), to request a particular QoS for a particular traffic flow. In RSVP, a traffic flow passes a request for service that includes additional information to help a network device decide how to apply QoS. This approach can take advantage of detailed knowledge of different traffic flows produced by an application. However, there is no way to determine whether the RSVP requests comply with network-wide policies. The result is that the devices are often configured to ignore the signaling and treat all traffic equally.

Another problem with RSVP signaling is that it involves signaling overhead, and generally cannot work with applications that generate short-lived flows. By the time the signaling gets to the network device, the flow may be over.

Still another approach is IP precedence, in which a value is placed in a sub-field of the IP Type of Service field. This provides even less granular QoS control than DS.

Thus, current approaches do not adequately extend network device QoS features to multiple applications. These approaches do not integrate the application into the network and do not enable the application to classify its flows according to application-specific information.

Further, it is difficult to track applications that use dynamic port numbers, such as FTP. While some network devices can track applications with dynamic port numbers to a limited extent, provided that the protocols are well known and simple, it is extremely difficult to track proprietary applications or protocols, or to track applications in environments that use encrypted traffic.

Still another deficiency of prior approaches is that there is no clear separation of the tasks of policy definition and configuration among the typical enterprise network administrator and the application manager. If a policy-based system is used but applications are not integrated into it, then problems may arise. Either a network administrator does both policy definition and configuration, without adequate knowledge of the application, or an application manager carries out classification of application flows but does not know how the network will treat QoS requests of the application.

Thus, there is a need for a mechanism that integrates applications into a policy-based networking system, and enables applications to participate in deciding how to apply a particular QoS to a traffic flow generated by the application.

SUMMARY OF THE INVENTION

The foregoing objects and advantages, and other objects and advantages that will become apparent from the following description, are achieved by the present invention, which comprises, in one embodiment, a method of selectively associating a quality of service value with a flow of information generated by an application program and directed to a network device. The method involves creating one or more mappings, each mapping representing an abstract policy and associating a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program. The mappings are stored in a repository that is accessible by the application program. The mappings are converted into one or more settings of the network device, which enforces the policy in response to receiving traffic from the application program that matches the traffic flow type.

One feature of this embodiment is that creating and storing one or more mappings comprises registering one or more application codepoints, which are associated with traffic flow types, in the repository. Another feature is that creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in the repository in association with information identifying the application program. A related feature is that creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy store that is coupled to the repository, in association with information identifying the application program.

Still another feature is that creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a directory. In one embodiment, creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy server coupled to a Lightweight Directory Access Protocol directory that comprises the repository.

According to another feature, creating and storing one or more mappings further comprises creating and storing, in the repository, one or more mappings of application codepoints of the application program to one or more Differential Services Code Points of a protocol associated with the network device. A related feature is that creating and storing one or more mappings further comprises generating one or more messages in a RSVP+ protocol and communicating the messages to the network device.

In another feature, determining one or more processing policies comprises creating and storing one or more policy statements in a repository, wherein each policy statement associates a condition of one of the traffic flows, an operator, an operand, and an action comprising one of the quality of service treatments. Further, determining one or more processing policies may comprise creating and storing one or more policy statements in a repository. Each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising one of the quality of service treatments.

In another feature, determining one or more processing policies comprises creating and storing one or more policy statements in a directory, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising one of the quality of service treatments, and wherein the plurality of nodes is coupled to a root node having a distinguished name in the directory. Still another feature is that each of the mappings comprises an application codepoint value stored in associated with a differentiated services code point value.

According to another feature, enforcing one of the processing policies comprises requesting an operating system function to modify a packet of the traffic flows using a policy element that requests a different operating system function according to the operating system then in use. At the network device, in response to receiving traffic from the application program that matches the traffic flow type and in response to the operating system function, the packet is modified to activate a quality of service treatment of the network device.

Other features and aspects will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements and in which:

FIG. 1A is a partial block diagram of a network message.

FIG. 1B is a partial block diagram of a network message.

FIG. 1 C is a partial block diagram of a network message.

FIG. 2 is a simplified block diagram of a computer network.

FIG. 3 is a simplified partial block diagram of a local policy enforcer.

FIG. 4 is a block diagram of a process of determining application quality of service information.

FIG. 5 is a block diagram of a portion of a Repository that contains a Directory Schema.

FIG. 6A is a block diagram of a system that provides policy-based QoS treatment for application traffic flows.

FIG. 6B is a block diagram of the system of FIG. 6A showing structures relating to multi-platform support.

FIG. 7A is a flow diagram of steps of a configuration phase of operating the system of FIG. 6A and FIG. 6B.

FIG. 7B is a flow diagram of steps of an active phase of operating the system of FIG. 6A and FIG. 6B.

FIG. 8 is a block diagram of a computer system with which an embodiment may be carried out.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A method and apparatus for policy-based management of quality of service treatments of network data traffic flows, by integrating policies with application programs, is described. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

OPERATIONAL CONTEXT

1. NETWORK

An embodiment of the invention is used in the context of a network. FIG. **2** is a block diagram of a computer network **200** that includes a plurality of local area networks **202, 204, 206** interconnected by a plurality of intermediate network devices **208, 210**. A plurality of network end stations, such as end station **212** and print server **214**, are coupled to the LANs. The network further includes at least one policy server **216** that may be coupled to a repository **218** and to a network administrator station **220**. A server suitable for use as policy server **216** is any Windows NT® or UNIX workstation or similar computer platform. Network **200** also includes at least one host or server **222** configured in accordance with the present invention.

Server **222** includes at least one application program or process **224**, a flow declaration component **226** and a communication facility **228**. The flow declaration component **226** includes a message generator **230** that communicates with the communication facility **228**. Flow declaration component **226** also is coupled to an associated memory **232** for storing one or more traffic flow data structures **234**. The application program **224** communicates with both communication facility **228** and, through application programming interface (API) layer **236**, to flow declaration component **226**. Communication facility **228**, in turn, is connected to network **200** by LAN **206**. The server **222** also comprises conventional programmable processing elements, which may contain software program instructions pertaining to the methods of the present invention. Other computer readable media may also be used to store the program instructions.

Communication facility **228** preferably includes one or more software libraries for implementing a communication protocol stack allowing server **222** to exchange messages with other network entities, such as end station **212**, print server **214**, etc. In particular, the communication facility **228** may include software layers corresponding to TCP/IP, Internet Packet Exchange (IPX) protocol, the AppleTalk protocol, the DECNet protocol and/or NetBIOS Extended User Interface (NetBEUI). Communication facility **228** further includes transmitting and receiving circuitry and components, including one or more network interface cards (NICs) that establish one or more physical ports to LAN **206** or other LANs for exchanging data packets and frames.

Intermediate network devices **208, 210** provide basic bridging functions including filtering of data traffic by MAC address, "learning" of a MAC address based upon a source MAC address of a frame, and forwarding of the frame based upon a destination MAC address or route information field (RIF). They may also include an IP software layer and provide route processing, path determination, and path switching functions. In one embodiment, devices **208, 210** are computers having transmitting and receiving circuitry and components, including network interface cards (NICs) establishing physical ports, for exchanging data frames. Intermediate network device **210**, moreover, preferably is configured as a local policy enforcer for traffic flows originating from server **222**, as described below.

Network **200** is illustrated as an example only. Embodiments disclosed in this document will operate with other, possibly far more complex, network topologies. For example, repository **218** and network administrator station **220** may be coupled directly or indirectly to policy server **216** through zero or more intermediate devices.

2. LOCAL POLICY ENFORCER

FIG. **3** is a block diagram of intermediate network device **210**, which is configured as a local policy enforcer and therefore referenced using the same reference numeral. Local policy enforcer **210** generally comprises a traffic flow state machine engine **310** for maintaining flow states corresponding to server **222** traffic flows, as described below. Local policy enforcer **210** may be present in any network device, or in any host. For example, local policy enforcer **210** may be implemented in a scheduler of a router or in a host module that enforces flows exiting a host.

The traffic flow state machine engine **310** is coupled to a communication engine **312**. Communication engine **312** is configured to formulate and exchange messages with the policy server **216** and flow declaration component **226** at server **222**. Thus, communication engine **312** includes or has access to conventional circuitry for transmitting and receiving messages over network **200**.

The traffic flow state machine engine **310** also is coupled to several traffic management resources and mechanisms. In particular, traffic flow state machine engine **310** is coupled to a packet/frame classifier **314**, a traffic conditioner entity **316**, a queue selector/mapping entity **318**, and a scheduler **320**. The traffic conditioner entity **316** includes several sub-components, including one or more metering entities **322**, one or more marker entities **324**, and one or more shaper/dropper entities **326**. The queue selector/mapping entity **318** and scheduler **320** operate on the various queues established by local policy enforcer **210** for its ports and/or interfaces, such as queues **330***a*–**330***e* corresponding to interface **332**.

The term "intermediate network device" broadly means any intermediate device for interconnecting end stations of a computer network, including, without limitation, Layer **3** devices or routers as defined by RFC **1812**; intermediate devices that are partially compliant with RFC **1812**; intermediate devices that provide additional functions such as Virtual Local Area Network (VLAN) support; and Layer **2** intermediate devices such as switches and bridges, etc.

POLICY SYSTEM

1. ARCHITECTURE

FIG. **6A** is a block diagram of a system that provides policy-based QoS treatment for application traffic flows. Generally, the system of FIG. **6A** comprises a Policy Server **604**, a Repository **600**, and an Application **608**.

The Application **608** generally is an enterprise software application program that runs on a server computer. For example, Application **608** may comprise an Oracle® database system, a PeopleSoft® human resources system, or any other application. Application **608** is coupled to Repository

600 and to an Application Manager 606, the functions of which are described further below. Application 608 is also coupled to a Local Mapping 610, described below.

Repository 600 stores polices that are associated with applications. Repository 600 may comprise a directory server, such as Netware Directory Server, Windows Active Directory, etc., or a database. Advantageously, use of a Repository offers security. The format of the Repository is known only to a network vendor that supplies the Repository, or to a network administrator. Thus, only authorized applications may access the Repository. The format of the Repository may be standardized, in which case any application complying with the standards can get access to the information. The Repository may be implemented as a table or information tree in a database or directory. Each directory or database can store many Repositories, each of which stores different information.

A Schema stored in the Repository provides an integration point and a common information model for communication between Application 608 and Policy Server 604. Application 608 extends the Schema by adding application-specific parameters to it. The extended Schema describes the application and its specific parameters. For example, the Schema describes an Application Codepoint and its possible values. When Application 608 is a Web server, the Schema describes a URL and its user name. Other examples of parameters include type of transaction; user identifier; application identifier; a text description; and others.

The application-specific parameters may be added manually, for example, using a schema definition file that is uploaded into the Repository 600. In another embodiment, the Repository 600 is a Directory Server compatible with Lightweight Directory Access Protocol (LDAP), and the application-specific parameters are added dynamically using LDAP. The precise mechanism for adding parameters is not critical. What is important is that each application contacts the Repository and declares one or more parameters that the application will use for classification of QoS of network devices that handle traffic flows generated by the application.

Policy Server 604 provides a mechanism by which a network administrator or manager may map application parameters into network services. A Network Administration Client 602 is coupled to Policy Server 604. A network administrator may use Network Administration Client 602 to communicate with Policy Server 604. Alternatively, Network Administration Client 602 may communicate directly with the Repository. Each network service defines how an application should access it. For example, access may comprise setting a DiffServ Code Point in the packets, by setting IP Precedence values in the packets, or by signaling using RSVP. An example of a commercial product suitable for use as Policy Server 604 is CiscoAssure QoS Policy Manager 1.0, commercially available from Cisco Systems, Inc.

Policy Server 604 is coupled to one or more network devices 620, each of which executes a network device operating system 622. An example of a network device 620 is a router and an example of a network device operating system 622 is IOS. Policy Server 604 configures the network devices 620 to implement the network services and to correctly respond to signaling from Application 608. For example, Policy Server 604 may map an Application Codepoint to a DiffServ Code Point or IP precedence value. Such mappings of ACPs to DSCPs may be stored in Local Mapping 610 so that they are immediately accessible to Application 608 when it is executing in real time.

Alternatively, each network device 620 may communicate directly with the Repository 600, without passing communications through Policy Server 604.

A mapping may apply for all application instances, for all application instances running on some subnet or on a single machine, or for a single instance identified by its IP address and source port number. The latter is useful, for example, when several Web servers are running on the same host. Thus, different mappings can be defined for the same Application Codepoints, depending on the particular installation instance. The mapping translates single application QoS requirements into policies or requests that are centrally coordinated and in compliance with network-wide multi-application policies.

In addition, each application instance may be associated with a role, or a combination of roles. Different mappings reflecting different policies may be associated with different roles. An application instance uses the mapping associated with it according to its name, IP address, port number, or role.

FIG. 6B is a block diagram of the system of FIG. 6A showing architectural details that provide multi-platform support. As in FIG. 6A, Policy Server 604 and Application 608 are coupled to a repository, which in this embodiment is implemented in the form of an LDAP-compliant Directory 601. Policy Server 604 and Application 608 communicate with Directory 601 using LDAP function calls.

Application 608 is tightly coupled to or integrated with an application QoS policy element 609. In one embodiment, element 609 is one or more software programs, processes, or modules that can be linked to application 608 and called by the application. Element 609 implements the functions described herein including those of FIG. 7B. Element 609 may communicate with Directory 601 using LDAP calls.

Element 609 can set QoS services of a network device, for example, by setting DiffServ bits of packets of a flow of application 608, using functions of a UNIX operation system 630 and a Windows NT operating system 632. Any other operating system may be supported; UNIX and Windows NT are illustrated merely as examples. In one embodiment, element 609 selectively and alternatively calls the "setsockopt" function or "RAPI" function of UNIX, or the GQoS or TC APIs of Windows NT to set QoS bits of packets of a particular application flow. The "setsockopt" function is used to activate DiffServ, and RAPI is used for RSVP. As a result, DiffServ or RSVP+ information is created, as indicated by block 634. The QoS information of block 634 is passed in packets of the flow to network device operating system 622. In response, network device 620 applies a desired QoS to the flow.

Advantageously, the architecture of FIG. 6B supports multiple platforms using APIs, provides policy integration using LDAP, and supports both DiffServ and RSVP+.

2. OPERATION OF THE SYSTEM

Operation of the system of FIG. 6A or FIG. 6B generally comprises two phases: a configuration phase and an operation phase. The phases may execute in parallel.

FIG. 7A is a flow diagram of steps that may be carried out in the configuration phase. In block 702, ACPs associated with an application are registered in a repository. For example, Application 608 registers one or more Application Codepoints in Repository 600. In one embodiment, Application 608 directly registers ACPs in Repository 600. Alternatively, Application Manager 606 receives information about traffic flows from Application 608, classifies the

traffic flows into groups, maps the groups to ACPs, and registers the ACPs in Directory **600**.

In block **704**, policies are established based on the ACPs that are registered in association with the application. In one embodiment, Network Administration Client **602** or a network manager receives the ACP values. The network manager need not receive information about Application **608** or its traffic flows, however, the network manager or Network Administration Client **602** normally has extensive knowledge about managed devices in the network and the QoS services and features that they support. In response, the network manager establishes policies that associate conditions, operators, and the ACP values with actions or services of the devices. The policies may implement DiffServ or RSVP strategies. The policies may be stored in a storage device. Definition and storage of policies may be carried out using Policy Server **604**.

In block **706**, the ACPs are mapped to DiffServ Code Points and the resulting mapping is stored in a repository. For example, Policy Server **604** may use one or more LDAP calls to store mappings of ACP values to DSCP values in Repository **600**. In the preferred embodiment, block **706** also involves automatically storing the mappings in a Local Mapping that is associated with and accessible to the application when it is executing.

FIG. **7B** is a flow diagram of an active phase of operating the system. Application **608** executes. When an ACP is reached in execution of Application **608**, the application calls its Local Mapping and passes it an ACP value associated with the current ACP, as shown by block **708**. Alternatively, the application fetches mapping information from the Repository. When the Repository is an LDAP Directory, the application may use LDAP calls to fetch the information. In this embodiment, the application is modified or configured so that the application is LDAP-enabled, for example, by incorporating LDAP reference code or libraries.

Block **708** may also involve the steps of processing the information received from the Repository for efficient lookup. In another embodiment, block **708** involves polling the Repository for policy changes that are stored in the Repository after the mapping information is retrieved. Further, block **708** may involve listening for notification of policy changes.

For each flow generated by the application, this information is then used to map the application parameters attached to the flow into a concrete QoS decision and a signaling mechanism. For example, the process is notified by the application about the start of each flow, with its parameters, and this information is converted into QoS information usable by a network device. The simplest case is mapping one ACP into a DSCP value, as shown by block **710**, and then setting a QoS value of packets of the flow, as shown by block **712**. For example, a QoS value may be set by marking the flow packets using an appropriate operating system call to an existing QoS service, as shown by block **714**.

Alternatively, if the mapping information cannot be obtained or refreshed from the policy Repository, the application reverts to a backup mode of signaling the policy information itself, such as an ACP value, to the network device, e.g., using RSVP+, as shown by block **716**. Thus, for short-lived flows, packets may be colored, whereas for long-lived flows, separate out-of-band messages may be used to establish QoS.

Standard APIs provided by the network operating system are used to signal the network. For example, GQOS or RAPI may be used for RSVP signaling. The APIs "GQoS" and "setsockopt" of the host operating system, such as UNIX or Windows®, may be used for DiffServ or IP Precedence marking.

The application and the policy system may use event services, such as CNS, to publish and subscribe to event notifications regarding policy changes. Upon such events the application should download and use the new policies. Alternatively, the application can poll the policy repository.

In block **718**, the policy is enforced at a network device, based on information identifying the source of the packet and the DSCP or RSVP+ value associated with the packet. In one embodiment, a service of IOS enforces the policy based on the values.

The selection of DiffServ or RSVP+ as a policy enforcement mechanism is a matter of network policy. DiffServ is integrated in the network using the Repository described herein, with the defined Schema and LDAP for communications, and can handle all sessions, including short-lived flows. RSVP+ is integrated using a network device that supports RSVP+. It enables signaling QoS information from non-core or third-party applications, and is well suited for use with non-trusted hosts.

3. USER MODEL

Using the system and process described above, network applications may request network QoS based on application-specific parameters. A network manager maps the application-specific parameters into concrete network services. However, this approach requires the network manager to be familiar with the application-specific parameters and what they mean. Some applications are complex, such as Enterprise Resource Planning ("ERP") applications, and require deep knowledge and expertise to operate properly. The network manager may not have such expertise. Normally such expertise resides with an application manager or information technology manager of the organization that is using the application.

FIG. **4** is a block diagram of a process of determining application-specific network QoS information. The process of FIG. **4** partitions decision-making about application QoS among an applications manager **420** and a network manager **422** in a manner that allows distributed decision-making yet is simple for the network manager to control.

Applications manager **420** is an individual who has expertise operating a particular application. Examples of applications include databases, ERP applications, sales force automation applications, human resources applications, etc. Applications manager **420** receives extensive application information **402** that defines, among other things, the types of network messages, traffic and flows that are generated by the application in operation. Applications manager **420** makes an application decision **404**, resulting in creating one or more application classes **406** that categorize the messages, traffic and flows into a smaller number of groups. For example, application information **402** might inform applications manager **420** that a particular application generates eight (8) different kinds of log and warning error messages. The applications manager may decide to classify all such messages as "medium" priority traffic.

The mapping of application information to application classes may be represented by creating and storing one or more Application Codepoints (ACPs) **426**. Thus, the application pre-defines a set of application classes or Application Codepoints **426**. The ACPs identify and define one or more types of traffic flows or classes that are produced by application. ACPs may define application flows in a static

manner, for example, according to intrinsic application parameters. For example, one ACP value may be associated with all traffic generated by a specific application module. Another ACP may identify batch traffic, and another may identify transactional traffic.

Table 1 provides one example of a mapping of ACPs to priority descriptions.

TABLE 1

ACP	DESCRIPTION
1	HIGH PRIORITY
2	MEDIUM PRIORITY
3	NORMAL PRIORITY
4	LOW PRIORITY

Table 2 provides another example of a mapping of ACPs to application traffic flow description.

TABLE 2

ACP	DESCRIPTION
1	FINANCE TRANSACTION
2	FINANCE REPORTING
3	HR TRANSACTION
4	HR REPORTING

Sequential ACP values are shown in Table 1 and Table 2, however, an ACP may have any value, according to any order. Any number of ACP values may be defined. The number of ACPs that are defined depends upon the level of detail ("granularity") of control that is desired for traffic flows of an application.

To establish ACPs **426** for an application, an application manager **420** may edit a configuration file that maps ACP values to application flows. For example, application manager **420** could be a Webmaster who prepares a configuration file that maps URLs and users into pre-defined application classes such as High, Medium, and Low. Alternatively, application manager **420** is an individual who uses a management console provided with the application to control how application flows are mapped into different ACPs.

Network manager **422** is an individual having expertise in configuring, operating, and maintaining a network, such as network **200** of FIG. **2**. Network manager **422** receives the application classes **406** and, based on the network manager's accumulated expertise in network operations, makes a network decision **408** that maps each of the application classes **406** into one or more network classes **410**. The network classes **410** represent a mapping of a specific QoS for the network, typically in terms of DSCPs or RSVP+ messages. For example, the network manager **422** may decide to map the High class of traffic to DSCP "**52**."

Table 3 is an example of a mapping of ACP values to policy values.

TABLE 3

ACP DESCRIPTION	DSCP VALUE
FINANCE TRANSACTION	50
FINANCE REPORTING	32
HR TRANSACTION	32
HR REPORTING	24

A mapping of the type shown in Table 3 is created and stored for each application. Accordingly, the ACP Description values will differ according to the application.

Preferably, such mappings are stored in the Repository in the manner described in this document. The mappings may be created and stored using an external application program. Preferably, the program creates and stores a default policy value, e.g., a default DSCP value, when no mapping is created for a particular ACP value. This simplifies the mapping process.

Both network manager **422** and applications manager **420** may be influenced by external management **424** and its policies and procedures.

In operation, the application consults with the policy system in order to complete the mapping from the ACPs into network services, for example, into DSCP values. Generally, such mapping is stored in the Repository. The policy manager uses the policy system to store the mappings in the Repository, and an application uses an access protocol such as LDAP to retrieve a mapping from the Repository.

The mapping from ACPs to network services may be communicated between applications manager **420** and network manager **422** using a Service Level Agreement (SLA). Generally, SLAs define the types of services provided by the network along with their characteristics, their limitations, and how to activate them. For example, an SLA might indicate, in part, that bandwidth of more than **20**Kbps may be obtained by using the DSCP value "43". Advantageously, applications manager **420** only needs to prepare a mapping of an application function into an ACP and may ignore details of the network services that are used to achieve a particular QoS. Further, network manager **422** only needs to prepare a mapping of ACPs to network services and need not know or consider the application functions that are handled.

As a result, network manager **422** considers only groups or classes of application traffic flow and need not know or consider a much larger set of application functions that fall into such groups or classes. Minimizing the number of ACPs will optimize the local policy matching process. Further, flexibility and granularity in decision-making are supported, because the application manager **420** may consider all application parameters and permutations before determining application policies. Accordingly, application managers may participate in the decision process pertaining to QoS for applications. A network administrator may control even the most complicated applications, which might involve many application-specific parameters and require extensive application-specific expertise.

4. INFORMATION MODEL

In an embodiment, the Repository stores one or more Policy Statements. Each Policy Statement applies to a specific application, and may be specific to a logical instance of the application. It describes a condition and a network service to be applied for traffic matching that condition. A Policy Statement may comprise a general Boolean expression of its underlying policy conditions.

Each condition describes a subset of traffic flows of the application. Each condition comprises basic condition components. Each basic condition comprises a basic policy parameter identifier, an operator and an operand. Policy identifiers may be application-specific. Each policy identifier has a pre-defined type such as string, integer, or enumerated value. For example, a policy identifier may be "URL"; an operator may be "contains"; and an operand may be "www.cisco.com".

A plurality of global, pre-defined Policy Identifiers are stored. Pre-defined Policy Identifiers include source and destination IP address, source and destination port numbers, protocol, application identifier, and ACP. Application-

specific policy identifiers are added to the Repository manually, or by a configuration file provided by the application, or by program calls using standard protocols such as LDAP.

FIG. **5** is a block diagram of a portion of a Repository that contains a Directory Schema **500**. The Directory Schema **500** may represent the topology of a managed network or other directory information useful in network management. A Root node **502** is coupled to Directory Schema **500**. In this context, "Root" means that node **502** is the topmost node for a set of nodes that represent Policy Statements. The Root node **502** may have a Distinguished Name in the Directory Schema **500** of the type defined in the International Telecommunications Union (ITU) X.**400** standard.

As shown in FIG. **5**, Root node **502** is coupled to a plurality of Application nodes **504A**, **504B**, **504C**. There may be any number of Application nodes. Each Application node represents a particular application program that is used in the managed network. Child nodes of an Application node represent policies that are associated with that application.

Each Policy Statement in the Repository comprises stored information that represents a condition and an action involved in the policy. For example, Application node **504A** is coupled to two Condition nodes **506A**, **506B**. Each condition comprises a parameter, an operator, and an operand. For example, a parameter may be a range of ACP values, or one or more URL statements that contain strings. Each operator is a comparison such as equal to, greater than, less than, in range, etc. Each condition evaluates to a Boolean value.

Conditions are joined by Boolean operators. For example, Condition node **506A** is coupled to Condition node **506B** by an AND operator **508**. There may be any number of Condition nodes and any number of operators.

The Repository is associated with a list of network services that are implemented by the system. The list of services stores abstract definitions of services that are later translated into a specific configuration of a network device. Examples of services include delay, guaranteed bandwidth, a queuing type on a router interface, etc. The services in the list also define signaling mechanisms that may be used for accessing the service, for example, by using a specific DSCP or IP Precedence value.

Each Policy Statement terminates in an Action. For example, Condition nodes **506A**, **506B** terminate at Action node **510**. Each Action node represents an action to apply to network devices when an associated application generates a traffic flow such that the Policy Statement evaluates to TRUE. An Action node may store information that indicates, for example, that network devices must service the flow using DSCP or IPP.

The Repository may be implemented in the form of a Directory Server, in a database, or using one or more files expressed in an Interface Definition Language (IDL).

HARDWARE OVERVIEW

FIG. **8** is a block diagram that illustrates a computer system **800** upon which an embodiment of the invention may be implemented. Computer system **800** includes a bus **802** or other communication mechanism for communicating information, and a processor **804** coupled with bus **802** for processing information. Computer system **800** also includes a main memory **806**, such as a random access memory (RAM) or other dynamic storage device, coupled to bus **802** for storing information and instructions to be executed by processor **804**. Main memory **806** also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor **804**. Computer system **800** further includes a read only memory (ROM) **808** or other static storage device coupled to bus **802** for storing static information and instructions for processor **804**. A storage device **810**, such as a magnetic disk or optical disk, is provided and coupled to bus **802** for storing information and instructions.

Computer system **800** may be coupled via bus **802** to a display **812**, such as a cathode ray tube (CRT), for displaying information to a computer user. An input device **814**, including alphanumeric and other keys, is coupled to bus **802** for communicating information and command selections to processor **804**. Another type of user input device is cursor control **816**, such as a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor **804** and for controlling cursor movement on display **812**. This input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), that allows the device to specify positions in a plane.

The invention is related to the use of computer system **800** for policy-based management of quality of service treatments of network data traffic flows by integrating policies with application programs. According to one embodiment of the invention, policy-based management of quality of service treatments of network data traffic flows by integrating policies with application programs is provided by computer system **800** in response to processor **804** executing one or more sequences of one or more instructions contained in main memory **806**. Such instructions may be read into main memory **806** from another computer-readable medium, such as storage device **810**. Execution of the sequences of instructions contained in main memory **806** causes processor **804** to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

The term "computer-readable medium" as used herein refers to any medium that participates in providing instructions to processor **804** for execution. Such a medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device **810**. Volatile media includes dynamic memory, such as main memory **806**. Transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise bus **802**. Transmission media can also take the form of acoustic or light waves, such as those generated during radio-wave and infra-red data communications.

Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, punchcards, papertape, any other physical medium with patterns of holes, a RAM, a PROM, and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave as described hereinafter, or any other medium from which a computer can read.

Various forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to processor **804** for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote computer can load the instruc-

tions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to computer system **800** can receive the data on the telephone line and use an infra-red transmitter to convert the data to an infra-red signal. An infra-red detector can receive the data carried in the infra-red signal and appropriate circuitry can place the data on bus **802**. Bus **802** carries the data to main memory **806**, from which processor **804** retrieves and executes the instructions. The instructions received by main memory **806** may optionally be stored on storage device **810** either before or after execution by processor **804**.

Computer system **800** also includes a communication interface **818** coupled to bus **802**. Communication interface **818** provides a two-way data communication coupling to a network link **820** that is connected to a local network **822**. For example, communication interface **818** may be an integrated services digital network (ISDN) card or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, communication interface **818** may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface **818** sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

Network link **820** typically provides data communication through one or more networks to other data devices. For example, network link **820** may provide a connection through local network **822** to a host computer **824** or to data equipment operated by an Internet Service Provider (ISP) **826**. ISP **826** in turn provides data communication services through the world wide packet data communication network now commonly referred to as the "Internet" **828**. Local network **822** and Internet **828** both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link **820** and through communication interface **818**, which carry the digital data to and from computer system **800**, are exemplary forms of carrier waves transporting the information.

Computer system **800** can send messages and receive data, including program code, through the network(s), network link **820** and communication interface **818**. In the Internet example, a server **830** might transmit a requested code for an application program through Internet **828**, ISP **826**, local network **822** and communication interface **818**. In accordance with the invention, one such downloaded application provides for policy-based management of quality of service treatments of network data traffic flows by integrating policies with application programs as described herein.

The received code may be executed by processor **804** as it is received, and/or stored in storage device **810**, or other non-volatile storage for later execution. In this manner, computer system **800** may obtain application code in the form of a carrier wave.

In the foregoing specification, the invention has been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A method of selectively associating a quality of service with a flow of information generated by an application program and directed to a network device, comprising the steps of:

creating one or more mappings, each mapping representing an abstract policy and associating a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program;

storing the mappings in a repository that is accessible by the application program;

converting the mappings into one or more settings of the network device that may be used by the network device to enforce the policy at the network device in response to receiving traffic from the application program that matches the traffic flow type.

2. A method as recited in claim **1**, wherein creating and storing one or more mappings comprises registering one or more application codepoints, which are associated with traffic flow types, in the repository.

3. A method as recited in claim **1**, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in the repository in association with information identifying the application program.

4. A method as recited in claim **1**, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy store that is coupled to the repository, in association with information identifying the application program.

5. A method as recited in claim **1**, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a directory.

6. A method as recited in claim **1**, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy server coupled to a Lightweight Directory Access Protocol directory that comprises the repository.

7. A method as recited in claim **1**, wherein creating and storing one or more mappings further comprises creating and storing, in the repository, one or more mappings of application codepoints of the application program to one or more Differential Services Code Points of a protocol associated with the network device.

8. A method as recited in claim **1**, wherein creating and storing one or more mappings further comprises generating one or more messages in a RSVP+ protocol and communicating the messages to the network device.

9. A method as recited in claim **1**, wherein the abstract policy for each mapping is determined by creating and storing one or more policy statements in a repository, wherein each policy statement associates a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

10. A method as recited in claim **1**, wherein the abstract policy for each mapping is determined by creating and storing one or more policy statements in a repository, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

11. A method as recited in claim **1**, wherein the abstract policy for each mapping is determined by creating and storing one or more policy statements in a directory, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of

service treatment, and wherein the plurality of nodes is coupled to a root node having a distinguished name in the directory.

12. A method as recited in claim 1, wherein each of the mappings comprises an application codepoint value stored in associated with a differentiated services code point value.

13. A method as recited in claim 1, wherein the abstract policies are enforced by creating and storing messages requesting an operating system function to modify a packet of the traffic flows using a policy element that requests a different operating system function according to the operating system then in use; and at the network device, in response to receiving traffic from the application program that matches the traffic flow type and in response to the operating system function, modifying the packet to activate a quality of service treatment of the network device.

14. A method of selectively associating a quality of service with a flow of information generated by an application program and directed to a network device, comprising the steps of:

creating one or more mappings, each mapping associating a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program;

storing the mappings in a schema of a directory that is accessible by the application program, the schema including a root node associated with the mappings of each application;

converting the mappings into one or more settings of the network device;

enforcing the quality of service at the network device in response to receiving traffic from the application program that matches the traffic flow type.

15. A computer-readable medium carrying one or more sequences of instructions for selectively associating a quality of service with a flow of information generated by an application program and directed to a network device, wherein execution of the one or more sequences of instructions by one or more processors causes the one or more processors to perform the steps of:

creating one or more mappings, each mapping representing an abstract policy and associating a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program;

storing the mappings in a repository that is accessible by the application program;

converting the mappings into one or more settings of the network device that may be used by the network device to enforce the policy at the network device in response to receiving traffic from the application program that matches the traffic flow type.

16. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings comprises registering one or more application codepoints, which are associated with traffic flow types, in the repository.

17. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in the repository in association with information identifying the application program.

18. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy store that is coupled to the repository, in association with information identifying the application program.

19. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a directory.

20. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings comprises creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy server coupled to a Lightweight Directory Access Protocol directory that comprises the repository.

21. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings further comprises creating and storing , in the repository, one or more mappings of application codepoints of the application program to one or more Differential Services Code Points of a protocol associated with the network device.

22. A computer-readable medium as recited in claim 15, wherein creating and storing one or more mappings further comprises generating one or more messages in a RSVP+ protocol and communicating the messages to the network device.

23. A computer-readable medium as recited in claim 15, wherein the abstract policy for each mapping is determined by creating and storing one or more policy statements in a repository, wherein each policy statement associates a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

24. A computer-readable medium as recited in claim 15, wherein the abstract policy for each mapping is determined by creating and storing one or more policy statements in a repository, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

25. A computer-readable medium as recited in claim 15, wherein the abstract policy for each mapping is determined by creating and storing one or more policy statements in a directory, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment, and wherein the plurality of nodes is coupled to a root node having a distinguished name in the directory.

26. A computer-readable medium as recited in claim 15, wherein each of the mappings comprises an application codepoint value stored in associated with a differentiated services code point value.

27. A computer-readable medium as recited in claim 15, wherein enforcing one of the abstract policies comprises:

requesting an operating system function to modify a packet of the traffic flows using a policy element that requests a different operating system function according to the operating system then in use;

at the network device, in response to receiving traffic from the application program that matches the traffic flow type and in response to the operating system function, modifying the packet to activate a quality of service treatment of the network device.

28. A system for selectively associating a quality of service with a flow of information generated by an application program and directed to a network device, comprising:

a policy manager that creates one or more mappings, each mapping representing an abstract policy and associat-

ing a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program, wherein the mappings are stored in a repository that is accessible by the application program;

a local storage element that converts the mappings into one or more settings of the network device that cause the network device to enforce the policy in response to receiving traffic from the application program that matches the traffic flow type.

29. A system as recited in claim **28**, the mappings comprise one or more application codepoints that are associated with traffic flow types and registered in the repository.

30. A system as recited in claim **28**, wherein the mappings comprise one or more policies, concerning network processing of traffic flows generated by the application program, that are stored in the repository in association with information identifying the application program.

31. A system as recited in claim **28**, wherein the repository comprises a directory server.

32. A system as recited in claim **28**, wherein the mappings comprise one or more policies, concerning network processing of traffic flows generated by the application program, stored in a policy server coupled to a Lightweight Directory Access Protocol directory that comprises the repository.

33. A system as recited in claim **28**, wherein the mappings comprise one or more mappings, stored in the repository, of application codepoints of the application program to one or more Differential Services Code Points of a protocol associated with the network device.

34. A system as recited in claim **28**, further comprising one or more policy statements stored in the repository, wherein each policy statement associates a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

35. A system as recited in claim **28**, further comprising one or more policy statements stored in the repository, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

36. A system as recited in claim **28**, further comprising one or more policy statements stored in a directory, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment, and wherein the plurality of nodes is coupled to a root node having a distinguished name in the directory.

37. A system as recited in claim **28**, wherein each of the mappings comprises an application codepoint value stored in associated with a differentiated services code point value.

38. A system as recited in claim **28**, further comprising an application quality of service policy element configured for requesting an operating system function to modify a packet of the traffic flows using a policy element that requests a different operating system function according to the operating system then in use and, at the network device, in response to receiving traffic from the application program that matches the traffic flow type and in response to the operating system function, modifying the packet to activate a quality of service treatment of the network device.

39. An apparatus for selectively associating a quality of service with a flow of information generated by an application program and directed to a network device, comprising:

means for creating one or more mappings, each mapping representing an abstract policy and associating a pre-determined network quality of service with a traffic flow type of the flow of information and with an application program;

means for storing the mappings in a repository that is accessible by the application program;

means for converting the mappings into one or more settings of the network device that may be used by the network device to enforce the policy at the network device in response to receiving traffic from the application program that matches the traffic flow type.

40. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for registering one or more application codepoints, which are associated with traffic flow types, in the repository.

41. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in the repository in association with information identifying the application program.

42. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy store that is coupled to the repository, in association with information identifying the application program.

43. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a directory.

44. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy server coupled to a Lightweight Directory Access Protocol directory that comprises the repository.

45. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for creating and storing, in the repository, one or more mappings of application codepoints of the application program to one or more Differential Services Code Points of a protocol associated with the network device.

46. An apparatus as recited in claim **39**, wherein the means for creating and storing one or more mappings further comprises means for generating one or more messages in a RSVP+ protocol and communicating the messages to the network device.

47. An apparatus as recited in claim **39**, wherein the abstract policy for each mapping is determined by means for creating and storing one or more policy statements in a repository, wherein each policy statement associates a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

48. An apparatus as recited in claim **39**, wherein the abstract policy for each mapping is determined by means for creating and storing one or more policy statements in a repository, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

49. An apparatus as recited in claim **39**, wherein the abstract policy for each mapping is determined by means for

creating and storing one or more policy statements in a directory, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment, and wherein the plurality of nodes is coupled to a root node having a distinguished name in the directory.

50. An apparatus as recited in claim **39**, wherein each of the mappings comprises an application codepoint value stored in associated with a differentiated services code point value.

51. An apparatus as recited in claim **39**, wherein the abstract policies are enforced by:

means for creating and storing messages requesting an operating system function to modify a packet of the traffic flows using a policy element that requests a different operating system function according to the operating system then in use; and

at the network device, in response to receiving traffic from the application program that matches the traffic flow type and in response to the operating system function, means for modifying the packet to activate a quality of service treatment of the network device.

52. An apparatus for selectively associating a quality of service with a flow of information generated by an application program and directed to a network device, comprising:

a network interface;

a processor coupled to the network interface and receiving information from the network interface;

a computer-readable medium accessible by the processor and comprising one or more sequences of instructions which, when executed by the processor, cause the processor to carry out the steps of:

creating one or more mappings, each mapping representing an abstract policy and associating a predetermined network quality of service with a traffic flow type of the flow of information and with an application program;

storing the mappings in a repository that is accessible by the application program;

converting the mappings into one or more settings of the network device that may be used by the network device to enforce the policy at the network device in response to receiving traffic from the application program that matches the traffic flow type.

53. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the step of registering one or more application codepoints, which are associated with traffic flow types, in the repository.

54. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the step of creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in the repository in association with information identifying the application program.

55. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the step of creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy store that is coupled to the repository, in association with information identifying the application program.

56. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the step of creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a directory.

57. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the step of creating and storing one or more policies, concerning network processing of traffic flows generated by the application program, in a policy server coupled to a Lightweight Directory Access Protocol directory that comprises the repository.

58. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the step of creating and storing, in the repository, one or more mappings of application codepoints of the application program to one or more Differential Services Code Points of a protocol associated with the network device.

59. An apparatus as recited in claim **52**, wherein the step of creating and storing one or more mappings includes the steps of:

generating one or more messages in a RSVP+ protocol; and

communicating the messages to the network device.

60. An apparatus as recited in claim **52**, further comprising instructions for determining the abstract policy for each mapping by performing the step of creating and storing one or more policy statements in a repository, wherein each policy statement associates a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

61. An apparatus as recited in claim **52**, further comprising instructions for determining the abstract policy for each mapping by performing the step of creating and storing one or more policy statements in a repository, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment.

62. An apparatus as recited in claim **52**, further comprising instructions for determining the abstract policy for each mapping by performing the step of creating and storing one or more policy statements in a directory, wherein each policy statement is represented by a plurality of nodes that represent a condition of one of the traffic flows, an operator, an operand, and an action comprising a quality of service treatment, and wherein the plurality of nodes is coupled to a root node having a distinguished name in the directory.

63. An apparatus as recited in claim **52**, wherein each of the mappings comprises an application codepoint value stored in associated with a differentiated services code point value.

64. An apparatus as recited in claim **52**, further comprising instructions for enforcing the abstract policies by performing the steps of:

creating and storing messages requesting an operating system function to modify a packet of the traffic flows using a policy element that requests a different operating system function according to the operating system then in use; and

at the network device, in response to receiving traffic from the application program that matches the traffic flow type and in response to the operating system function, modifying the packet to activate a quality of service treatment of the network device.

* * * * *